

A massive bleeding – what can we do in prehospital tactical care? Combat lessons-learned

Ostra utrata krwi – co możemy zrobić w warunkach przedszpitalnych?
Doświadczenia pola walki

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Abstract. The authors presented the practical conclusions and therapeutic recommendations for the heavily bleeding patients, managed under combat conditions. Such therapy is vital for the wounded in the hostile tactical environment. The military medical solutions for assuring the effective hemostasis or applying the restrictive fluid therapy in internal bleeding cases may be useful also in civilian medicine.

Key words: hemorrhage, massive bleeding, tactical combat care

Streszczenie. Autorzy przedstawili praktyczne wnioski i zalecenia postępowania w przypadku wystąpienia krwotoków w warunkach pola walki. Ich stosowanie ma kluczowe znaczenie dla osiągnięcia sukcesu i przeżycia rannych w niesprzyjających warunkach środowiska taktycznego. Doświadczenia medycyny wojskowej i praktyczne rozwiązania w celu zapewnienia skutecznej hemostazy lub zachowania restrykcyjnej płynoterapii w przypadku krwotoków wewnętrznych mogą znaleźć zastosowanie również w cywilnej opiece przedszpitalnej.

Słowa kluczowe: krwotok, masywne krwawienie, polowa opieka nad rannym

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Massive bleeding is the most frequent cause of death under combat conditions. Limb trauma is currently the main cause of bleeding [1]. Modern tactical protective gear (a ballistic vest, a kevlar helmet) protect the torso and the head of a soldier. At the same time, limbs remain exposed to direct trauma. Bleeding from limbs is the most common, potentially reversible cause of death in the battlefield. Combat medics can manage it by applying direct pressure to the place of bleeding and using a pressure dressing such as emergency bandage, Olaes or a tactical tourniquet.

Conventional pressure is not, unfortunately, effective against bleeding into body cavities. This type of bleeding requires careful observation and management of the injured and, what is even more important, immediate evacuation of the injured to a level 2 field medical facility for the purposes

of care and appropriate surgical treatment.

A hemorrhage [2] is defined as the loss of:

- 1.5 ml/kg bodyweight/min of blood within 20 minutes,
- 150 ml/kg bodyweight/min of blood within 1 hour.

Taking appropriate therapeutic actions has an influence on the dynamics and effects of bleeding. These actions include:

- identification of a massive bleeding
- applying the scoop and run approach in the case of an internal hemorrhage,
- applying the stay and play approach in the case of an external hemorrhage,
- performing correct local hemostasis (direct compression, a tactical tourniquet, wound packing, a local hemostatic agent, a pressure clamp),

Table 1. Classification of blood loss by American College of Surgeons (for a 70 kg, male)
Tabela 1. Klasyfikacja utraty krwi Amerykańskiego Towarzystwa Chirurgów (dotyczy mężczyzny o masie ciała ok. 70 kg)

	Class I	Class II	Class III	Class IV
blood loss (ml)	<750	750-1500	1500-2000	>2000
blood loss (% blood volume)	<15	15-30	30-40	>40
Pulse rate (per minute)	<100	100-120	120-140	>140
Blood pressure	Normal or decreased	Decreased	Decreased	Decreased
Capillary refill time	Normal	Normal	Extended	Extended
Respiratory rate (per minute)	14-20	20-30	30-35	>35
Urine output (ml/h)	>30	15-30	5-15	Negligible
Mental status	Anxious	Anxious	Anxious, confused	Confused, lethargic
Fluid replacement	Crystalloid	Crystalloid	Crystalloid and blood	Crystalloid and blood

- influencing internal hemostasis (Tranexamic acid, TXA),
- preventing hypothermia,
- hypotensive fluid resuscitation (and fluids, if necessary)
- immobilization of fractures,
- pain management (ketamine vs. opioids)

A combat medic is expected not only to dress bleeding properly, but also, depending on the trauma sustained by a soldier, to predict possible blood loss. It is estimated that an adult may lose:

- 1000-1500 ml of blood from a damaged lung
- 2000 ml of blood from a damaged liver,
- 2000 ml of blood from a damaged spleen,
- 3000-5000 ml of blood in the case of pelvic trauma,
- 1500-2000 ml of blood due to a fractured femur,
- 1000 ml of blood due to a crus fracture,
- 800 ml of blood due to a humerus fracture,
- 400 ml of blood due to the fracture of a forearm bone.

A combat medic has to be familiar with this knowledge in order to plan appropriate treatment and implement a suitable fluid therapy and approach (scoop and run or stay and play) [3].

Hemorrhagic shock leads to tissue hypoxia and acidosis [4], thus increasing metabolic disturbances and worsening the patient's condition.

The classification of blood loss-related symptoms by the American College of Surgeons (ACS) from 1997 is a useful tool for combat medics. It allows them to classify the injured into four groups according to clinical symptoms, evaluate the approximate volume of blood loss and recommend the best form of fluid replacement.

Based on the analysis of previous armed conflicts, a tourniquet has been regarded in the second half of the twentieth century as an unsafe tool to stop bleeding due to a number of complications related to the ischemia of limb muscles and nerves, and the frequent ineffectiveness of the device, usually resulting from its inappropriate physical properties. It appears that now, thanks to recent changes in its design and positive recommendations after its use in Iraq (Operation Iraqi Freedom) and Afghanistan (Operation Enduring Freedom), a tourniquet is experiencing a revival. There are two types of tactical tourniquets recommended for the contemporary battlefield: CAT (Combat Application Tourniquet) and SOFTT-W (Special Operation Forces Tactical Tourniquet-Wide).

In the event of an exchange of fire (under fire), the first necessary action is to apply a tactical tourniquet to manage a life-threatening bleeding (Fig. 1 and 2). If actions taken as part of the tactical combat casualty care (TCCC) (direct compression, a pressure dressing) did not stop the bleeding, a medic should keep the pressure on the bleeding until surgical intervention, which should not exceed 2 hours [5,6].

According to the TCCC guidelines, a combat medic should apply a tactical tourniquet:

- during the care under fire phase – on a uniform, as proximally as possible on a wounded limb (applied by the wounded soldier or by a combat medic),
- during the tactical field care phase, in a safe (hidden) place – 2-3 inches above the wound, directly on the skin, if hemorrhage is impossible to stop by compression dressing or hemostatic agents (i.e. post-traumatic amputations).



Figure 1. CAT tourniquet
Rycina 1. Staza taktyczna CAT



Figure 2. SOFTT-W tourniquet
Rycina 2. Staza taktyczna SOFTT-W

- if applying a tourniquet does not stop the bleeding, check the pressure of the tourniquet or apply another tourniquet proximally (above the first one),
- since blood vessels may be hidden in the soft tissue between bones, hemostasis may be ineffective when applying compression to a forearm or a lower leg. If this is the case, it is recommended to apply a tourniquet to an arm or a thigh (one bone of which is along the limb axis) [5,7].

Tightening the tourniquet should stop the blood flow (no pulse) in a limb below the tourniquet. To indicate that the tourniquet has been applied, a combat medic should also mark the forehead or the cheek of the wounded soldier with a large letter "T", and also mark the tourniquet and the soldier's skin with the time of tightening and include the time in documentation. In the case of prolonged evacuation, consider releasing pressure from the limb after 2 hours, but before doing so, use a combat gauze (QuikClot, Celox) as a local hemostatic agent. Apply pressure for at least 3 minutes using the combat gauze for direct contact with the wound and a normal gauze as a top layer. Release the tightened tourniquet only if the wounded soldier has a normal hemodynamic response to the administered fluids, which is reflected in the recovery of normal peripheral pulse and the improvement of mental status (if the soldier does not additionally suffer from a head trauma). In other words, if the wounded soldier is under the risk of a fatal bleeding, the priority is to save the life and not the limb. At any rate, keeping the tourniquet tightened for longer than 2 hours does not always lead to a limb amputation. The risk of complications resulting from limb ischemia and reperfusion injury is, however, greater in that case.

A tactical tourniquet is effective in stopping a limb bleeding but it should be used only when other

measures do not stop the bleeding (according to the evaluation by a trained medic).

Kragh et al. [6] have demonstrated that the use of a tactical tourniquet has direct influence on survival in 87% of the studied patients ($p < 0.001$) and prevents the occurrence of hemorrhagic shock in 90% of the studied patients ($p < 0.001$). They have also shown that the fatality rate was higher among cases where the tourniquet was applied with delay (11% under pre-hospital conditions and as much as 24% after admission to hospital, $p = 0.05$). In 5 cases there were indications for the use of a tourniquet but other measures were applied, which turned out to be ineffective. As a consequence, the patients did not survive.

Kragh et al. [8] have also revealed that the application of 428 tourniquets in 232 patients (to 309 wounded limbs) did not increase fatality rate among the patients (lack of dependence) and did not lead to amputation. Only 4 patients (1.7%) suffered from complications in the form of residual paresthesia. The percentage of fasciotomies was 28% in patients whose time of tourniquet application was ≤ 2 hours (75 of 272 patients) and 36% in patients whose time of tourniquet application was > 2 hours (9 of 25 patients, $p = 0.4$).

Nevertheless, the American College of Surgeons allows medics to use a tourniquet as part of Advanced Trauma Life Support only as a last resort, when direct pressure fails, accepting the tourniquet as a measure of choice in the case of post-traumatic amputation [9]. It also recommends using pneumatic pressure in hospital conditions. Swan's study [10] compares the effectiveness of tourniquets with direct compression to blood vessels in pressure points (commonly learned as part of first aid) in 10 healthy volunteers. The endpoint of the study was the loss of signal of distal blood flow in the vessel, as monitored by the Doppler device. Results of the study indicate that



Figure 3. QuikClot Combat Gauze

Rycina 3. Gaza hemostatyczna QuikClot

while the application of a tourniquet is fully effective, using pressure points is ineffective at controlling bleeding.

What is crucial in this matter is to provide medical personnel and battlefield operators with training on tourniquet application to control limb bleeding, which should minimize the percentage of preventable deaths caused by massive external bleeding in the battlefield.

Hemostatic agents used in the battlefield

There are two substances in use currently:

- Kaolin - zeolite (QuikClot),
- Chitosan (Celox, HemCon, WoundStat, ChitoGauze, ChitoFlex).

Kaolin is an inert volcanic mineral containing silicon and clay, which is impregnated in the form of a combat gauze [Fig. 3]. It is non-toxic and it does not cause allergy. The currently used third generation of wound dressings with kaolin does not trigger adverse exothermic reactions that lead to tissue burns. The mechanism of hemostatic action is based on the activation of an internal coagulation cascade. Kaolin absorbs water from the surrounding area, activates factor XII, platelets and facilitates the formation of fibrin. Since the mineral is not biodegradable and removing it from the wound used to be problematic (it was used in the form of granules), it is currently used in the forms of a rolled or a Z-folded QuikClot combat gauze [Fig. 3] and a clotting sponge (QuikClot ACS+) [11,12].



Figure 4. Celox Gauze

Rycina 4. Gaza hemostatyczna Celox

Chitosan is manufactured from crustacean shells. It is a linear polysaccharide used in the form of granules. The mechanism of hemostatic action is based on the formation of a pseudo-clot and a gel dressing as a result of the exchange of electric charges between the substance and erythrocytes. Chitosan is a biodegradable material. Lysozyme breaks it down to glucosamine. It is used in the form of granules (Celox D), a dispenser with granules for penetrating wounds (Celox A), a gauze impregnated with the active substance (Celox Gauze [Fig. 4]) and adhesive dressing (HemCon). Advantages of chitosan include effectiveness at stopping bleeding in patients treated with warfarin derivatives or heparin and effective use in hypothermic patients, as the substance retains its hemostatic properties in contact with blood whose temperature lowers to 13-18°C [11,12].

Local hemostatic agents should be used in body areas where a tactical tourniquet cannot be applied (the torso) and in the cases of junctional hemorrhage (occurring in the area of the neck, the axillary fossa or the groin). They are a better alternative to a tourniquet when it is necessary to stop local bleeding from a limb, even though they cannot replace the tourniquet in all cases.

The use of a hemostatic agent must be accompanied by the application of constant pressure for at least 3-5 minutes.

The American army presently recommends QuikClot and HemCon as hemostatic agents [7,11]. Soldiers in Polish military contingents are equipped with an individual medical kit (IPMed) which includes QuikClot (*combat gauze*) and Celox (*gauze*). Tactical operators and combat medics undergo training to learn what measure and what form of the measure they should use to achieve effective hemostasis.



Figure 5. Combat Ready Clamp (CRoC)

Rycina 5. Combat Ready Clamp (CRoC)



Figure 6. Junctional Emergency Treatment Tool (JETT)

Rycina 6. Junctional Emergency Treatment Tool (JETT)



Figure 7. Abdominal Aortic & Junctional Tourniquet (AAJT)

Rycina 7. Abdominal Aortic & Junctional Tourniquet (AAJT)

Pressure clamps

Estimates suggest that damage to great vessels in the pelvis is the cause of approximately 25% of hemorrhages. Bleeding from great vessels requires direct pressure [1,13,14]. In order to ensure effective action and release the hands of the medic applying the pressure, 3 systems to stop bleeding are currently in use:



Figure 8. Israeli emergency bandage

Rycina 8. Opatrunek izraelski

- Combat Ready Clamp (CRoC [Fig. 5]),
- Junctional Emergency Treatment Tool (JETT [Fig. 6]),
- Abdominal Aortic & Junctional Tourniquet (AAJT [Fig. 7]).

Their action is based on the external mechanical compression of groin tissues and the common iliac artery from one (CRoC) or two (JETT) sides or on the pneumatic pressure, the purpose of which is to compress the abdominal aorta and iliac arteries by increasing abdominal pressure (AAJT).

TCCC guidelines recommend using a pressure clamp or the local application of a hemostatic agent, combined with applying direct pressure to the groin, depending on whether a device is unavailable or ready for use [5].

Pressure dressing

External bleeding is frequently the effect of trauma, both in the battlefield and in the civilian environment. Luckily, not every bleeding is heavy, which means that taking such aggressive measures as the application of a pressure clamp or a local hemostatic agent is not always a necessity.

The Emergency Bandage, also called the Israeli bandage, is a recognized measure for stopping bleeding [Fig. 8]. Manufactured for the army in four sizes (including the size for dressing abdominal wounds), the Emergency Bandage is elastic and contains a one-layer or a two-layer gauze pad with a clamp on top that is used to exert directional pressure.

Another practical measure is Olaes Modular Bandage (Fig. 9), which is designed as a "3 in 1" pressure solution. The elastic roll of the bandage features a plastic pressure pad and a gauze to pack a wound. The bandage also has sewn in Velcro® control strips, which prevent the roll from accidental unwrapping.



Figure 9. OLAES Modular Bandage

Rycina 9. Opatrunek OLAES

Wound packing

Some believe that direct pressure and appropriate wound packing with gauze is more important in stopping bleeding than the influence of a local hemostatic agent [12,15]. This is why tactical emergency training puts emphasis on the development and improvement of manual abilities to appropriately pack a wound using gauze, regardless of whether a hemostatic agent is used to manage bleeding wounds or not.

Tranexamic acid (TXA)

This active substance has been known for years and is currently experiencing a revival thanks to recommendations by the Committee on the Tactical Combat Casualty Care. It belongs to fibrinolysis inhibitors (dissolving blood clots) and prevents plasminogen from activation to plasmin. Indications for use in the battlefield are the following: symptoms of hemorrhagic shock, one or more severe amputations and penetrating wounds of the torso or multiple sources of bleeding. TCCC guidelines recommend administering 1 g of tranexamic acid (Exacyl®) in 100 ml of physiological NaCl solution or lactated Ringer's solution as quickly as possible and no later than 3 hours after trauma. The second dose of TXA (1 g) should be applied after administering Hextend (HAES, a colloidal solution) or after alternative fluid therapy [5]. It is used by medics under combat conditions.

Hypotensive fluid resuscitation

Tactical medics examining a shock may find the following evaluation parameters particularly useful: the mental state, the presence of radial pulse and its rate. Other useful (but not required) parameters include blood pressure, respiration rate, capillary refill time, anxiety and the sense of deadly threat [3,7].

Guidelines regarding the administration of crystalloid solutions are in contrast to restrictive guidelines for fluid

therapy under combat conditions (intravenous, without fluids or transfusing small volumes of colloids).

TCCC guidelines and US Army procedures for prehospital management of the injured soldier with identified hemorrhage dictate the following:

- if the bleeding has been stopped and there are no symptoms of shock, do not transfuse fluids;
- if the bleeding has been stopped and there are symptoms of shock, administer a 500 ml bolus of Hextend (HAES) intravenously; repeat after 30 minutes if shock symptoms persist (do not administer more than 1000 ml of Hextend),
- do not transfuse fluids in the case of uncontrolled internal (abdominal, thoracic) bleeding [5,7]. Hypotensive fluid resuscitation aims to maintain approximately 75% of the value of normal blood pressure, so that systolic blood pressure does not exceed 90 mm Hg and MAP is 40-50 mm Hg.

Reducing intravenous fluid administration prevents the occurrence of coagulopathy resulting from dilution [3,7].

In the case of hypotensive patients with penetrating trauma of the torso and severe head trauma, it is recommended to administer hypertonic NaCl solution in hydroxyethyl starch (HyperHAES) as part of fluid resuscitation [16,17].

Normal rules for fluid resuscitation and crystalloids (see Table 1) should be applied:

- in hemodynamically stable patients,
- after stopping isolated external bleeding that is not compression resistant,
- in severe head traumas (maintain the systolic blood pressure of <110 mm Hg),
- in burns,
- in the case of crush syndrome.

Hypothermia

Lowering body temperature by 1°C results in a 10-percent decrease in the ability to form a clot. Hypothermia, along with coagulopathy and acidosis, is a major pathomechanism contributing to the death of the injured person due to bleeding. Since warm fluids are not available under combat conditions, thermal equipment, such as the Ready Heat Blanket, and protective evacuation equipment, such as the Blizzard Survival Blanket and the Hypothermia Prevention and Management Kit (HPMK), is used to insulate the injured soldier and protect him or her against heat loss. Hypothermia prevention is a key factor in preventing the occurrence of systemic coagulation disturbances and fatal causes of bleeding diathesis [18].

Immobilization of fractures

External stabilization of fractures (if possible, by the use of traction in the case of a fractured limb and compression in the case of pelvic fracture) significantly reduces bleeding and the need for analgesics. It is one of the priorities in the management of bleeding patients with fractures; a combat medic should immobilize a fracture after the careful

examination of the injured patient and the performance of emergency procedures (stopping the bleeding, clearing the airways, relieving a tension pneumothorax).

Pain management under combat conditions

The latest TCCC guidelines do not recommend administering opioids to patients with shock symptoms because opioids may disturb natural compensation mechanisms and worsen the patient's condition [19].

In the case of moderate to severe pain, and if the patient does not suffer from hemorrhagic shock and is not under the threat of shock, a medic should administer 800 mg of oral transmucosal fentanyl citrate (OTFC).

However, when the patient has symptoms of hemorrhagic shock or is under the threat of the shock, opioids should not be administered; instead, ketamine should be administered at the dose of 50 mg (intramuscular or by the use of an autoinjector) or 20 mg (intravenous or intramedullary gradual administration). A medic may repeat an intramuscular dose after 30 minutes and an intravenous dose after 20 minutes. The endpoint of the therapy is pain relief or the occurrence of nystagmus in the patient [5].

Summary

Delaying emergency procedures for stopping bleeding increases the risk of cardiovascular failure and decompensation in patients with rapid bleeding, even if a patient has been provided with fluid therapy. Therefore, guidelines for combat and tactical care indicate that stopping limb or junctional hemorrhage (occurring in the area of the neck, the axillary fossa or the groin) is a priority and should be performed even before clearing the airways. The indication results from an assumption that a human body handles short-term hypoxia more easily than the effects of hemorrhagic shock, bearing in mind major limitations of the tactical environment, delay in evacuation and limited access to blood preparations. Medical training of soldiers puts strong emphasis on the ability to apply a tactical tourniquet correctly, pack a wound and use modern hemostatic agents, which are included in the soldier's personal equipment.

Bleeding into body cavities, on the other hand, requires immediate evacuation of the patient in order to implement surgical procedures for the management of bleeding. Tactical care of the injured soldier requires the prudent use of fluid therapy, the prevention of hypothermia and the administration of an appropriate analgesic.

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